PMP®
PROJECT MANAGEMENT PROFESSIONAL

6

Introducing Project Time Management

There's an old joke when it comes to project management time: "The first 90 percent of a project schedule takes 90 percent of the time. The last 10 percent takes the other 90 percent of the time."

And isn't that the way it goes? Hopefully not, but far too often, yes. Projects, especially projects that are running behind schedule, fail at the beginning, not the end. The importance of planning a project is never as evident until the rush to completion. The final actions to complete a project are dependent on the plans and motivations set in the project planning processes.

Effective project management requires adequate time for planning—and based on the results of planning, adequate time for implementation of those plans. In this chapter, we'll discuss how project activities are decomposed and then how the work packages are sequenced, calculated, and accounted for. We'll also discuss the art and science of estimating the time for work packages in new and familiar projects. Once the work's been decomposed, we'll create and visualize the network diagram.

Time management is an essential element on the PMP exam. You'll need a solid understanding of the activities and methods to predict and account for project time. Time management is crucial to not only passing the PMP exam, but also to successful project management.

Defining the Project Activities

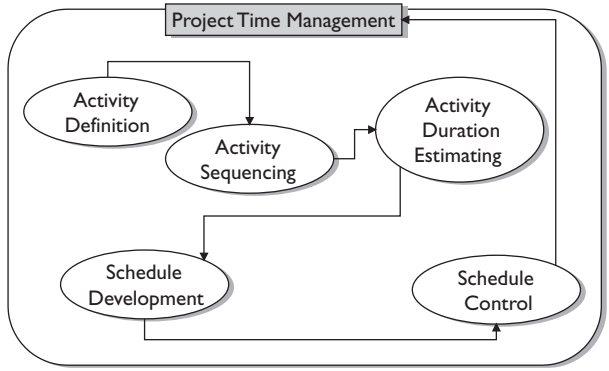
Projects are temporary undertakings to create a unique product or service. The idea of time is inherent to the very definition of a project in that all projects are temporary. Projects may seem to last forever, but sooner or later they must end. Adequate planning of the temporary project can predict when a project will end. Within this short, limited time, the project manager must create something: a product or a service. The creation is about change—and change, as you may have guessed, takes time. Figure 6-1 shows the components of project time management.

Creation of the product or service comes about due to the work the project team completes. The sum of the time of the work equates to when the project is completed. In addition to the duration of activities, there are other factors of time to consider:

- Project management activities
- Planning processes
- The sequence of activities

FIGURE 6-1

Time management relies on several inputs to help build and control the schedule.



- Procurement
- Reliance on internal and external events
- Known and unknown events affecting the project

Project time management is based predominantly on planning, and then it's all control and execution. Planning for project schedules may stem from deadlines, customer demands, hard and soft logic, and a bit of prediction.

Considering the Inputs to Activity Definition

The activity list is an output of activity definition, and includes all of the activities to be performed within the project. The list must be in alignment with the project scope. Remember the project scope? It's a description of all the required work, and only the required work, to complete the project. In a sense, the activity list is a further definition of the project scope since it includes only those actions needed to complete the project scope.

Creating the activity list relies on several completed documents, knowledge, and actions. The creation of the activity list uses the following as inputs to the process:

- **WBS** The WBS serves as a major input in the creation of the activity list. Recall from Chapter 5 that the WBS is a deliverables-orientated collection of project components. It is not a collection of activities to create the deliverables.
- **Scope statement** It is a description of the required work, and only the required work, to complete the project.

- **Historical information** If the project's been done before, what activities were included in the similar project? Historical information is proven information that the project manager can rely on for creating activity lists.
- **Constraints** What restrictions are imposed on the project manager and the project team? For example, is there a deadline for the project? A predetermined budget? Demanded quality metrics? These are examples of constraints.
- **Assumptions** What assumptions have been identified for the project work? For example, consider the availability of resources, acceptable weather, and time allotments to complete the project.
- **Expert judgment** Expert judgment allows experts to influence decisions in regard to the needed work packages.

Decomposing the Project Work Packages

The WBS, the collection of deliverable-orientated components, must now be broken into activities. Specifically the work packages within the WBS must be decomposed into manageable work elements. What's the difference between decomposing the project deliverables and the project work? The elements in the WBS are deliverables; this process is concerned with the actions needed to create the deliverables.

It's quite possible to create the WBS and the activity list in tandem. Don't get too caught up in the timing of the activity list definition and the WBS. Simply put, the WBS describes the components of the deliverables; the activity list defines the actions to create the deliverables.

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The creation of the WBS and the activity list is not a solo activity. The WBS and the activity list are created with the project team.

Relying on Templates

Why reinvent the wheel? If similar projects have been completed in the past, rely on the WBS and activity lists from this historical information to serve as a template for the current project. Even if a portion of a project is similar, a project manager can use the activity list and focus on the similarities of the current project.

A template can include several elements to make a project manager's life easier and the new project more successful:

- Required actions to complete the project scope
- Required resources and skills
- Required hours of duration for activities
- Known risks
- Outputs of the work
- Descriptions of the work packages
- Supporting details

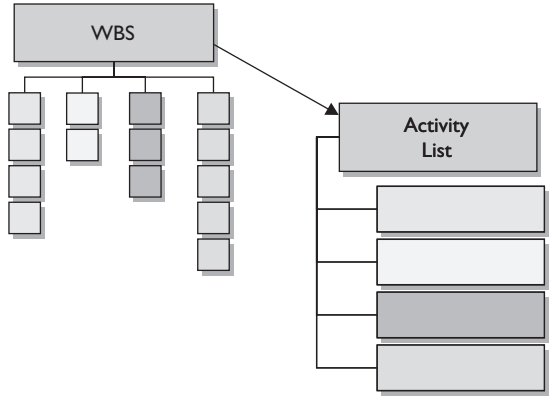
Compiling the Activity List

Ta-dah! The primary output of decomposing the work is the activity list. The activity list is a collection of all of the work elements required to complete the project. The activity list is actually an extension of the WBS, and will serve as a fundamental tool in creating the project schedule. The activity list is needed to ensure that all of the deliverables of the WBS are accounted for and that the necessary work is mapped to each of the deliverables as shown in Figure 6-2.

The activity list also ensures that there is no extra work included in the project. Extra work costs time and money—and defeats the project scope. The correlation between the WBS and the work package is a one-to-one ratio: the deliverables in the WBS map to the required work. In other words, the WBS is comprised of all of the components the project will create. The activities list is comprised of all of the work required to create the components within the WBS.

FIGURE 6-2

Activity lists are organized as extensions of the WBS.



In addition, the work on the activity list includes descriptions of each identified activity. This accomplishes three things:

- Ensures the team members are in agreement on what the work package accomplishes
- Ensures the work supports and creates the WBS deliverables
- Ensures the work is within the project scope

Organizing the Supporting Detail

The supporting detail of the activity list must be documented, organized for fast reference, and accessible throughout the project implementation. The supporting detail allows the project manager, the project team, and other interested parties to reference the activity list definition process and recall why decisions were made and how the activity list was created. The supporting detail includes

- Assumptions
- Constraints
- Reasoning behind identified work package
- Information specific to the industry that the project is operating within

Updating the Work Breakdown Structure

When creating the activity list, the project team and the project manager may discover discrepancies or inadequacies in the existing WBS. Updates to the WBS allow the project manager to ensure that all of the needed project deliverables are included in the WBS and then map the discovered deliverables to the identified work in the activity list.

In addition, the elements within the WBS may not be defined fully or correctly. During the decomposition of the work, elements of the WBS may need to be updated to reflect the proper description of the WBS elements. The description of the WBS should be complete and full—and leave no room for ambiguity or misinterpretation. Finally, updates to the WBS may also include cost estimates to the discovered deliverables.

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Updates to the WBS are called refinements. As the project moves towards completion, refinements ensure all of the deliverables are accounted for within the WBS. Refinements may also call for, indirectly, updates to the activity list.

Mapping the Activities

Now that the activity list has been created, the activities must be arranged in a logical sequence. This process calls on the project manager and the project team to identify the logical relationships between activities—and the preferred relationship between activities. This can be accomplished a few different ways:

- **Computer driven** There are many different scheduling and project management software packages available. These programs can help the project manager and the project team determine which actions need to happen in what order—and with what level of discretion.
- **Manual process** In smaller projects, and on larger projects in the early phases, manual sequencing may be preferred. An advantage of manual sequencing is that it's easier to move around dependencies and activities than in some programs.
- **Blended approach** A combination of manual and computer-driven scheduling methods is fine. It's important to determine the finality of the activity sequence, however. Sometimes a blended approach can be more complex than relying on just one or another.

on the Job

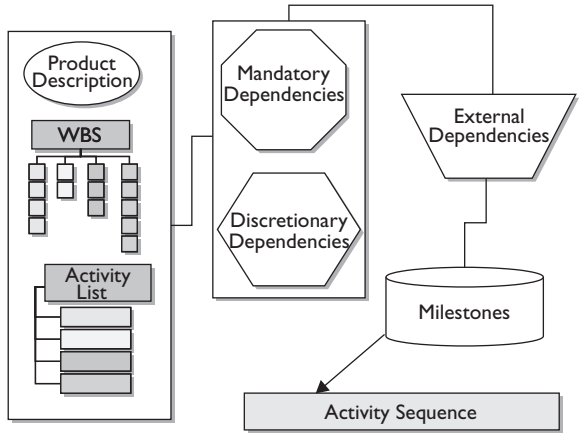
"Sticky notes" can help sequence events. Put your activities on sticky notes and then plot them out on a white board. Draw arrows to show the relationship between activities. Want to make a change? It's easy to rearrange the notes and the relationships.

Considering the Inputs to Activity Sequencing

Figure 6-3 shows the complete process of activity sequencing. There are many approaches to completing the activity sequencing. Perhaps the greatest approach, however, is that activity sequencing is done with the project team, not as a solo activity.

FIGURE 6-3

Activity sequencing relies on inputs to create the final sequence of events.



The project manager must rely on the project team and the inputs to activity sequencing:

- **Activity list** The activity list we've just discussed—it's the list of actions needed to complete the project deliverables.
- **Product description** The product description is needed since it may influence the sequence of events. For example, in construction, technology, or community planning (among other project types), the product description may include requirements that will logically affect the planning of activity sequencing.
- **Mandatory dependencies** These dependencies are the natural order of activities. For example, you cannot begin building your house until your foundation is in place. These relationships are called hard logic.
- **Discretionary dependencies** These dependencies are the preferred order of activities. Project managers should use these relationships at their "discretion" and document the logic behind the decision. Discretionary dependencies allow activities to happen in a preferred order because of best practices, conditions unique to the project work, or external events. For example, a painting project typically allows the primer and the paint to be applied within hours of each other. Due to the expected high humidity during the project, however, all of the building will be completely primed before the paint can be applied. These relationships are also known as soft logic, preferred logic, or preferential logic.

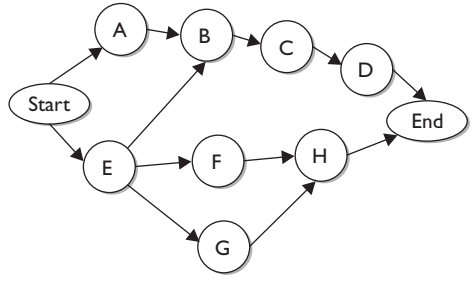
- **External dependencies** As its name implies, these are dependencies outside of the project's control. Examples include delivery of equipment from a vendor, the deliverable of another project, or the decision of a committee, lawsuit, or expected new law.
- **Milestones** Milestones must be considered and evaluated when sequencing events to ensure all of the work needed to complete the milestones is included.

Creating Network Diagrams

Network diagrams visualize the project work. A network diagram shows the relationship of the work activities and how the work will progress from start to completion. Network diagrams can be extremely complex or easy to create and configure. Most network diagrams in today's project management environment use an approach called "activity-on-node" to illustrate the activities and the relationship between activities. Older network diagramming methods used "activity-on-arrows" to represent the activities and their relationships.

Using the Precedence Diagramming Method

The Precedence Diagramming Method (PDM) is the most common method of arranging the project work visually. The PDM puts the activities in boxes, called nodes, and connects the boxes with arrows. The arrows represent the relationship and the dependencies of the work packages. The following illustration shows a simple network diagram using PDM.



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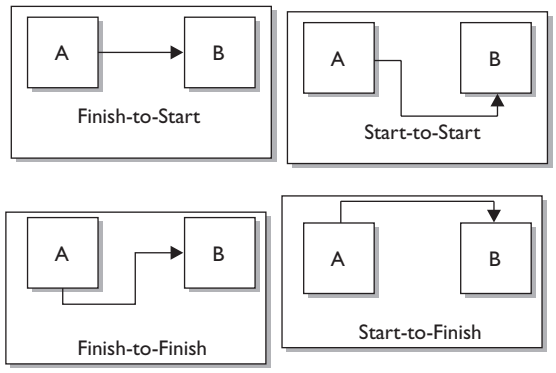
PDM is also known as AON— activity-on-node. It's the most common approach to network diagramming since it's used by most project management information systems but can also be done manually.

Relationships between activities in a PDM constitute one of four different types (as shown in Figure 6-4):

FIGURE 6-4

PDM relationships can vary, but most use the finish-to-start approach.



- **Finish-to-start (FS)** This relationship means Task A must complete before Task B can begin. This is the most common relationship. Example: The foundation must be set before the framing can begin.
- **Start-to-start (SS)** This relationship means Task A must start before Task B can start. This relationship allows both activities to happen in tandem. For example, a crew of painters is painting a house. Task A is to scrape the flecking paint off the house and Task B is to prime the house. The workers scraping the house must start before the other workers can begin priming the house. All of the scraping doesn't have to be completed before the priming can start, just some of it.
- **Finish-to-finish (FF)** This relationship means Task A must complete before Task B does. Ideally, two tasks must finish at exactly the same time, but this is not always the case. For example, two teams of electricians may be working together to install new telephone cables throughout a building by Monday morning. Team A is pulling the cable to each office. Team B is connecting the cables to wall jacks and connecting the telephones. Team A must pull the cable to the office so Team B can complete their activity. The activities need to complete at nearly the same time, by Monday morning, so the new phones are functional.
- **Start-to-finish (SF)** This relationship is unusual and is rarely used. It requires that Task A start so that Task B may finish. Such relationships may be encountered in construction and manufacturing. It is also known as just-in-time (JIT) scheduling. An example is a construction of a shoe store. The end of the construction is soon, but an exact date is not known. The owner of the shoe store doesn't want to order the shoe inventory until the completion of the construction is nearly complete. The start of the construction tasks dictates when the inventory of the shoes is ordered.

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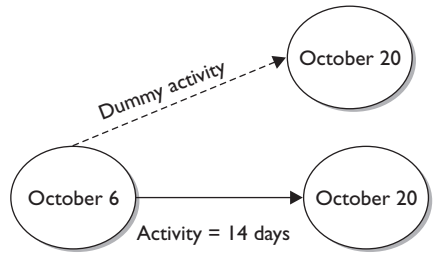
Only professional scheduling engineers should use the SS, FF, and SF relationships. Don't worry about the SF for your exam studying time; you likely won't encounter it.

Using the Arrow Diagramming Method

The Arrow Diagramming Method (ADM) approach to activity sequencing uses arrows to represent the activities. The arrows are "connected" on nodes. ADM only uses finish-to-start relationships. In some instances, dummy activities are required to express the logical relationship between two activities. A dummy activity is illustrated with a dashed arrow between the nodes. The following illustration is a simple example of an ADM network diagram.



ADM is an example of activity-on-arrow (AOA) networks. This approach is not as popular as PDM, but may still be prevalent in some industries. ADM can be created manually or through a PMIS.

Using Conditional Diagramming Methods

Conditional diagramming methods are more complex and structured than ADM or PDM. Conditional diagramming methods include system dynamics and the graphical evaluation and review technique (GERT). These models allow for loops and conditional branching. For example, GERT may require that tests of the product be performed several times before the project may continue. Based on the outcome of the testing, the project may use one of several paths to enable its completion. In addition, GERT allows for probabilistic clarification of work package estimates.

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Note that GERT allows for conditional advancement. ADM and PDM offer no loops or branching.

Utilizing Network Templates

Just as a project manager can rely on WBS templates, there may be network templates available to streamline the planning process or to conform to a predetermined standard. Network templates can represent an entire project if appropriate, though portions of a network template, such as the required project management activities, are common.

The portions of a network template are also known as subnets or fragnets. Subnets are often associated with repetitive actions within a network diagram. For example, each floor in a high-rise apartment building may undergo the same or similar actions during construction. Rather than complete the network diagram for each floor, a subnet can be implemented.

Examining the Sequencing Outputs

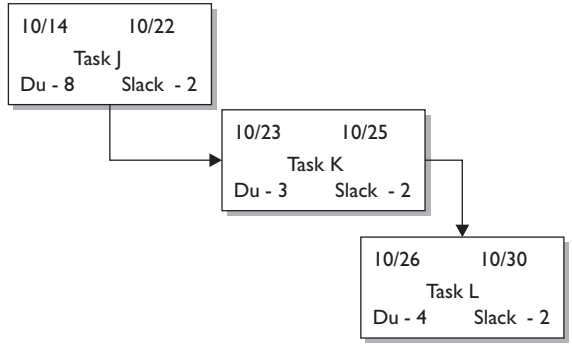
There are many approaches to using activity sequencing: a project manager and the project team can use software programs, the approach can be done manually, or the team can manually do the scheduling and then transfer the schedule into a PMIS. Whichever method is selected, the project manager must remember four things:

- Only the required work should be scheduled.
- Finish-to-start relationships are the most common and preferred.
- Activity sequencing is not the same as a schedule.
- Scheduling comes after activity sequencing.

Using a Project Network Diagram

Once the activity list has been put into sequential order, the flow of the project work can be visualized. A project network diagram (PND) illustrates the flow of the project work and the relationship between the work packages. PNDs are typically activity-on-node (AON) and most PMIS packages use the PDM method. The following illustration is typical example of a network diagram.

Network diagrams may also include summary activities, also known as hammock activities. Accompanying the network diagram, there should be an explanation of the workflow, why decisions were made, and details on any preferred logic the project manager may have used. Network diagrams may also be known as a PERT chart, though this term may be slightly inaccurate. PERT, Program Evaluation and Review Technique, is a specific network diagram using weighted averages. (More on PERT in a moment.)



Updating the Activity Lists

During the creation of the network diagram, assumptions about the activity sequence may reveal missing activities in the activity list. Just as the creation of the activity list may prompt the project team and the project manager to update the WBS, the creation of the network diagram may prompt the project team to update the activity lists.

While this may seem redundant, to update the activities list illustrated in the project network diagram, it is essential documentation. A reflection of the WBS, the activity list, and the network diagram should all support the project scope. A key stakeholder should be able to follow the logic of the WBS to the activity list, and from the activity list find all of the activities mapped in order.

Estimating Activity Durations

Ready for a loaded question? "Now how long will all of this take?" Project managers hear this one all the time, right? And maybe right after that: "How much will all of this cost?" We'll talk about cost estimates in Chapter 7. For now, let's talk about time.

The answer to the question "How long will it take?" depends on the accuracy of the estimates, the consistency of the work, and other variables within the project. The best a project manager can do is create honest estimates based on the information he's been provided. Until the schedule is finalized, no one will know the duration of the project.

The tasks are first identified, their duration is estimated, and then the sequencing of the activities takes place. These activities are required to complete the project schedule and the estimated project duration. These three activities are iterated as more information comes available. If the proposed schedule is acceptable, the project can move forward. If the proposed schedule takes too long, the scheduler can use a few strategies to compress the project. We'll discuss the art of sequencing in a few moments.

Activity duration estimates, like the activity list and the WBS, don't come from the project manager—they come from the people completing the work. Activity duration estimates may undergo progressive elaboration. In this section, we'll examine the approach to completing activity duration estimates, the basis of estimates, and allow for activity list updates.

Considering the Activity Duration Estimates Inputs

The importance of accurate estimates is paramount. The activity estimates will be used to create the project schedule, and predict when the project should end. Inaccurate estimates could cost the performing organization thousands of dollars in fines, lost

opportunities, loss of customers, or worse. To create accurate estimates, the project manager and the project team will rely on several inputs:

- **Activity lists** You know this right? Activity lists are the work elements necessary to create the deliverables.
- **Constraints** An identification of the project constraints is needed since they may influence the estimates. A deadline is an example of a constraint.
- **Assumptions** An identification of the assumptions is needed since work estimates may be influenced by the assumptions. For example, the team may be operating under an assumption that the project must be completed within one calendar year.
- **Resource requirements** Activity durations may change based on the number of resources assigned to the activity. For example, Task A may take eight hours with one person assigned to the work, but Task A may be completed in four hours with two team members assigned. Some activities, such as installing a computer operating system, will take the same amount of time regardless of how many resources are assigned. Project managers must also take care not to overload resources in an effort to complete a task; too many resources can be counterproductive.
- **Effort vs. duration** Effort is the amount of labor that is applied to a task. Duration is how long the task is expected to take with the given amount of labor. For example, a task to unload a freight truck may take eight hours with two people assigned to the task. If the effort is increased by adding more labor to the task (in this instance, more people), then the duration of the task is decreased. Some activities, however, have a fixed duration and are not affected by the amount of labor assigned to the task. For example, to install a piece of software on a computer will take the same amount of time if one computer administrator is completing the work or if two computer administrators are attempting to complete the work.
- **Resource capabilities** The abilities of the project team members must be taken into consideration. Consider a task in an architectural firm. Reason says that if a senior architect is assigned to the task, he will be able to complete it faster than if a junior architect were assigned to the same task. Material resources are also considered to influence activity time. Consider pre-drilled cabinets versus cabinets that require the carpenter to drill each cabinet as it is installed. The pre-drilled cabinets allow the job to be completed faster.
- **Historical information** Historical information is always an excellent source for information on activity duration estimates. Historical information can come from several sources:

- Historical information can come from project files of other projects within the organization.
- Commercial duration estimating databases can offer information on how long industry-specific activities should take. These databases should take into consideration the materials, the experience of the resources, and define the assumptions the predicted work duration is based upon.
- Project team members may recollect information regarding the expected duration of activities. While these inputs are valuable, they are generally less valuable than documented sources such as other project files or the commercial databases.
- **Identified risks** We'll discuss risk in detail in Chapter 11. Risks, good or bad, can influence the estimated duration of activities. The risks on each activity should be identified, analyzed, and then predicted as to their probability and impact. If risk mitigation tasks are added to the schedule, the mitigation activities will need their duration estimated and then sequenced into the schedule in the proper order.

Applying Expert Judgment

The project manager and the project team should utilize expert judgment if possible to predict the duration of project activities. Expert judgment can come from subject matter experts, project team members, and other resources, internal or external to the performing organization, that is familiar with the activities the project demands.

Estimating durations is not easy as there are many variables that can influence an activity's duration. Consider the amount of resources that can be applied to the resources, the experience of the resources completing this type of work, and their competence with the work packages.

A big dose of reality is also needed with activity duration estimates. Imagine an activity that has been estimated to take 40 hours. While on paper that looks like a typical workweek, it's pretty unlikely the task will be completed within one week. Why? Consider all the phone calls, impromptu meetings, e-mail, and other interruptions throughout the day. These slivers of time chip away at the actual productive hours within a workday. The project manager should find a base of actual productive hours per day based on typical interruptions, meetings, and so on; for example, six productive hours out of eight working hours is typical. Based on this assumption (that six hours out of a day are productive), this means a task slated to last 40 hours will actually take nearly seven working days to complete.

Creating an Analogy

Analogous estimating relies on historical information to predict what current activity durations should be. Analogous estimating is also known as top-down estimating and is a form or expert judgment. To use analogous estimating, the activities from the historical project are similar in nature and are used to predict what the similar activities in the current project will take.

A project manager must consider if the work has ever been done before, and if so, what help will the historical information provide. The project manager must consider the resources, project team members, and equipment that completed the activities in the previous project compared to the resources available for the current project. Ideally, the activities should be more than similar; they should be identical. And the resources that completed the work in the past should be the same resources used in completing the current work.

When the only source of activity duration estimates is the project team members, instead of expert judgment and historical information, your estimates will be uncertain and inherently risky.

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Analogous estimating uses historical information and is more reliable than predictions from the project team members.

Applying Quantitative Estimates

Quantitatively-based durations use mathematical formulas to predict how long an activity will take based on the "quantities" of work to be completed. For example, a commercial printer needs to print 100,000 brochures. The workers include two pressman and two bindery experts to fold and package the brochures. Notice how the duration is how long the activity will take to complete, while the effort is the total number of hours (labor) invested because of the resources involved. The decomposed work, with quantitative factors, is shown in Table 6-1.

TABLE 6-1 Decomposed Work, with Quantitative Factors

Workers	Units per hour	Duration for 100,000	Effort
Pressman (two)	5,000	20 hours	40 hours
Bindery (two)	4,000	25 hours	50 hours
Totals		45 hours	90 hours

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Duration is how long an activity takes, while effort is the billable time for the labor to complete the activity. Consider an activity that is scheduled to last 40 hours. The project manager must consider the cost of the person's time assigned to complete project work—for example, a senior full-time engineer versus a part-time person, at a lower cost. The senior engineer may be able to complete the activity in 40 consecutive work hours, but the cost of this employee's time may be more than the value of the activity. The part-time employee may be able to complete the task in two segments of 20 hours, but their time is billed at a substantially lower rate.

Factoring in Reserve Time

Parkinson's Law states: "Work expands so as to fill the time available for its completion." This little nugget of wisdom is oh-so-true. Consider a project team member that knows an activity should last 24 hours. The team member decides, in his own wisdom, to say the activity will last 32 hours. This extra eight hours, he figures, will allow plenty of time for the work to be completed should any unforeseen incidents pop-up. The trouble is, however, that the task will magically expand to require the complete 32 hours. Why does this happen? Consider the following:

- **Hidden time** Hidden time, the time factored in by the project team member, is secret. No one, especially the project manager, knows why the extra time has been factored into the activity. The team member can then "enjoy" the extra time to complete the task at leisure.
- **Procrastination** Most people put off starting a task until the last possible minute. The trouble with bloated, hidden time is people may wait through the additional time they've secretly factored into the activity. Unfortunately, if something does go awry in completing the activity, the work result is later than predicted.
- **Demands** Project team members may be on multiple projects with multiple demands. The requirement to move from project to project can shift focus, result in loss of concentration, and require additional ramp-up time as workers shift from activity to activity. The demand for multitasking allows project team members to take advantage of hidden time.
- **On schedule** Activities are typically completed on schedule or late, but rarely early. Users that have bloated the activity duration estimates may finish their task ahead of what they promised, but have a tendency to hold the results until the

activity was due. This is because workers aren't usually rewarded for completing work early. In addition, workers don't want to reveal the inaccuracies in their time estimates. Workers may believe future estimates may be based on actual work durations, rather than estimates, so they'll "sandbag" the results to protect themselves—and finish "on-schedule."

So what's a project manager to do? First off, the project manager should strive to incorporate historical information and expert judgment to predicate accurate estimates. Second, the project manager should stress a genuine need for accurate duration estimates. Finally, the project manager can incorporate a reserve time.

A reserve time is a percentage of the project duration or a preset number of work periods and is usually added to the end of the project schedule. Reserve time may also be added to individual activity durations based on risk or uncertainty in the activity duration. When activities are completed late, the additional time for the activity is subtracted from the reserve time. As the project moves forward, the reserve time can be reduced or eliminated as the project manager sees fit. Reserve time decisions should be documented.

Evaluating the Estimates

The end result of estimating activities provides three things:

- **Activity duration estimates** Activity duration estimates reflect how long each work package will take to complete. Duration estimates should include an acknowledgement of the range of variance. For example, an activity whose duration is expected to be one week may have a range of variance of one week ± three days. This means the work can take up to eight days, or as little as two days. This is assuming a week is five days.
- **Basis of estimates** Any assumptions made during the activity estimating process should be identified. In addition, any historical information, subject matter experts, or commercial estimating databases that were used should also be documented for future reference.
- **Activity list updates** During the estimating process, there may be discoveries of missing activities within the activity list. The project manager should confirm that the new work packages are reflected in the activity list for the project.

INSIDE THE EXAM

There's a ton of information in this chapter—all of it important—but there are some key things you must know to pass the PMP exam. For starters, you should understand how activity estimates are created.

Analogous estimates use historical information to predict how long current project activities will take place. These estimates are considered top-down estimates and are part of expert judgment. Quantifiable estimates, on the other hand, use a quantity to predict how long activities will take. Consider any unit such as square feet painted per hour or number of units created per day.

GERT is the only network diagram that allows for loops and conditional branching based on what the project has experienced to date. System dynamics is another example of conditional advancement.

When developing the schedule, the most common method is the CPM, though PERT and GERT may also be used. Lag is a positive time added to a task to indicate waiting. Lead is negative time added to a task to "hurry up." Fast tracking arranges activities to happen in tandem rather than in succession—this increases risk. Crashing adds more resources to activities to decrease their duration, which typically adds cost.

Monte Carlo Analysis is typically a computer program to estimate the many possible variables within a project schedule. Monte Carlo simulations predict probable end dates, not an exact end date. Another tool the project manager can use is *resource leveling*. Resource leveling smoothes out the project schedule so resources are not over-allocated. A result of this is that projects are often scheduled to last longer than initial estimates.

The critical path in a project has zero float, and is the path with the longest duration to completion. There can be more than one critical path in a network diagram. Should delays happen on non-critical paths, and all float is consumed, the critical path may change.

The project schedule is a calendar-based system used to predict when the project, and work, will start and end. Gantt charts map activities against a calendar and may show the relationship between activities. Milestone charts show when key deliverables are expected; they do not show the relationship between activities.

Developing the Project Schedule

Now that the estimates for the activities are completed, it's time to work some magic and see how long the entire project will take. The project manager specifically pursues the

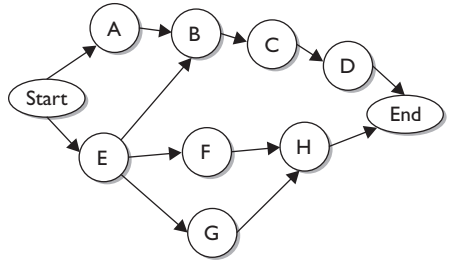
start date, and more importantly, the completion date. Projects that don't provide realistic schedules aren't likely to get approved. Or worse, the projects will get approved, but they will most likely fail, as the project team will not be able to meet the unrealistic schedule.

The creation of the project schedule is iterative. It's rare for a schedule to get created, approved, and implemented without some iterative examination, arrangement, and management input—though on smaller projects it may be possible. When activity list updates, constraints, assumptions and other inputs are considered, it's easy to see why scheduling can become complex.

Revisiting the Project Network Diagram

The PND illustrates the project. Recall that the PND shows the sequence of activities and the relationship between activities. The PND is important during schedule creation because it allows the project manager and the project team to evaluate the decisions, constraints, and assumptions that were made earlier in the process to determine why certain activities must occur in a particular order.

Hard logic and soft logic must be evaluated to confirm that the decisions and logic are feasible, accurate, and fit within the expected completion of the project. The following illustration is a simple PND for a small project.



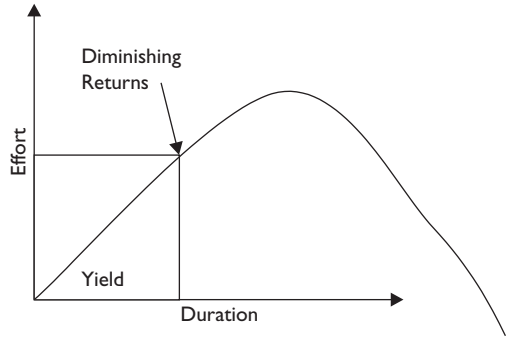
Relying on Activity Duration Estimates

Another key input to schedule creation is the activity duration estimates. Makes sense, right? The project manager needs to know how long the whole project will take, so the activity duration estimates will help calculate that number. Recall, however, the range of variances for each activity—these possible variances need to be accounted for in the actual project schedule creation. We'll discuss the schedule creation in a few moments.

Considering the Resource Requirements

The identified resource requirements will affect the project schedule. Remember the difference between duration and effort? Duration is how long the activity will take, effort is the labor applied to the task. For example, painting a building may take 80 hours to complete with two workers assigned to the job. Add two more workers and now the work will take only 40 hours.

The duration in the preceding example is 40 hours to complete the painting, but there will be 160 hours of effort on the activity. At some point in the work, the "duration to effort ratio" becomes saturated, and adding additional laborers will actually become counterproductive. This is subject to the law of diminishing returns. The following illustration demonstrates the previous example.



Considering the Resource Pool Availability

In a perfect world, all of the needed resources for a project would be available whenever the project manager says so. In the real world, and on your PMP exam, the availability of project resources fluctuate due to demands of other projects, demands of ongoing operations, personal lives, vacations, sick days, and more.

The availability of the project pool must be evaluated. If certain activities require a worker with a highly specialized skill, these activities are resource-dependent. Should the worker not be available for the timeframe of the required activity, one of several things must happen

- The project manager must negotiate to make the resource available for the activity in the project schedule.
- The activity must be moved in the schedule for when the resource is available.
- The activity, and possibly the project, must wait for the resource to become available.
- The project may incur additional costs by finding other resources to complete the scheduled work.

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When resources are needed but are not available, the project manager must negotiate to secure the resource. This may involve tradeoffs between projects or additional expenses as the activity is outsourced to a vendor to complete the work. The project manager does not want to delay the project waiting on a resource.

Considering the Calendars

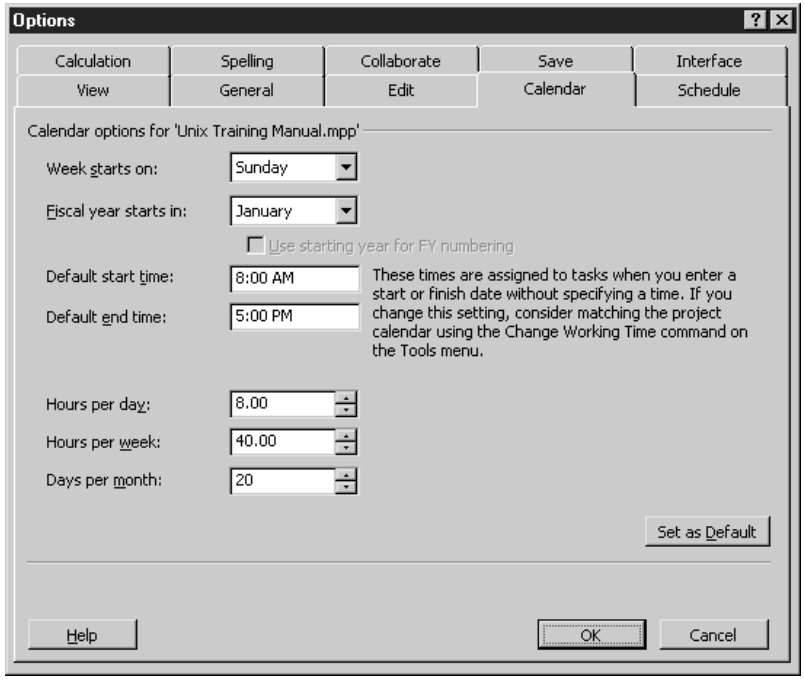
There are two calendar types that will affect the project:

- **Project calendar** This calendar shows when work is allowed on the project. For example, a project may require the project team to work nights and weekends so as not to disturb the ongoing operations of the organization during working hours. In addition, the project calendar accounts for holidays, working hours, and work shifts that the project will cover.
- **Resource calendar** The resource calendar controls when resources, such as project team members, consultants, and SMEs are available to work on the project. It takes into account vacations, other commitments within the organization, or restrictions on contracted work, overtime issues, and so on.

The consideration of the project calendar and the resource calendar is mandatory to predict when a project may realistically begin and end. Figure 6-5 shows the project calendar setting from Microsoft Project. Keep in mind the PMP exam is not concerned with which PMIS system is used, but the understanding of the role of the PMIS.

FIGURE 6-5

Project calendars determine when the project work will take place.



Evaluating the Project Constraints

Constraints will restrict when and how the project may be implemented. Constraints are added to a project for a purpose, not just to rush the work to completion. It is important to understand why the constraint has been imposed. Here are a few common examples of why constraints exist:

- To take advantage of an opportunity to profit from a market window for a product or service
- To work within the parameters of expected weather conditions (for seasonal or outdoor projects)
- To adhere to government requirements
- To adhere to industry regulations, best practices, or guidelines
- To work within timeframes that incorporate the expected delivery of materials from vendors or other projects

Perhaps one of the biggest constraints is the predetermined project deadline. Imagine a company creating a product to take to a tradeshow. If the creation of the product is running late, the tradeshow isn't going to move so that the product has enough time to be completed for the show. There are four time constraints to consider:

- **Start No Earlier Than (SNET)** This constraint requires that the project or activity not start earlier than the predetermined date. Consider an activity to add software to an existing network server in a technology project. The project manager adds a "Start No Earlier Than" constraint on the activity to ensure the activity begins on a Saturday when the server is not in use by the organization. The activity can begin any time after the preset date, but not before it.
- **Start No Later Than (SNLT)** This constraint requires the activity to begin by a predetermined date. For example, the creation of a community flower garden must "Start No Later Than" May 15. The creation of the garden may, weather permitting, begin earlier than the preset date, but it must start by that date.
- **Finish No Later Than (FNLT)** This constraint requires the project or activity to finish by a predetermined date. For example, the installation of flooring tile in a restaurant must be finished by October 25 so the kitchen

equipment can be installed. The constraint "Finish No Later Than" is tied to the date of October 25. The activity can end sooner than October 25, but not after it.

- **Finish No Earlier Than (FNET)** This somewhat unusual constraint requires the activity to be in motion up until the predetermined date. Consider a project to create a special blend of wine. The wine must be aged a specific amount of time before the winemaking process can continue; the process requires a set amount of time so it may "Finish No Earlier Than" the determined time. The activity can end any time after the preset date, but not before it.

Project constraints can also include milestones. The project sponsor may request, for example, a milestone for a deliverable within the project on April 28. Based on this milestone all of the work needed to create a deliverable must be scheduled against the expected due date. In addition, once these milestones are set, it's pretty darn tough to change them.

Milestone constraints can also be tied to activities outside of the project. Consider a scheduled walk-through with a customer on a construction project. Or consider the demands of a project to create a product or service by a scheduled milestone that another project within the performing organization is expecting.

Reevaluating the Assumptions

Assumptions are beliefs held to be true, but that may not necessarily be so. Assumptions, such as being able to have access to a building 24 hours a day, seven days a week, can wreak havoc on the project schedule if they are proved false. Consider a schedule that plans on working three shifts during a remodeling of an office building only to discover late in the project planning that the customer will not allow the work to happen during daytime hours. Assumptions factored into the project should be documented and accounted for.

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The "Start No Earlier Than" and the "Finish No Later Than" constraints are your best bets for exam answers since these are the most common constraints.

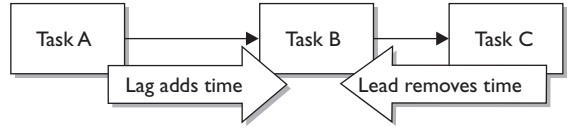
Remember that constraints can be tied to individual activities within the project, or to the entire project.

Considering Leads and Lags

Leads and lags are values added to work packages to slightly alter the relationship between two or more work packages. For example, a finish-to-start relationship may exist between applying primer to a warehouse and applying the paint. The project manager, in this scenario, has decided to add one day of lead-time to the work package painting the warehouse. Now the painting can begin one day before the priming is scheduled to end. Lead time is considered a negative value because time is subtracted from the downstream activity to bring it closer to the start of the project.

Lag time is waiting time. Imagine a project to install wood floors in an office building. Currently, there is a finish-to-start relationship between staining the floors and adding a layer of shellac to seal the wood floors. The project manager has elected, because of the humidity in the building, to add two days of lag time to the downstream activity of sealing the floors. Now the shellac cannot be applied immediately after the stain, but must wait two additional days. Lag is considered a positive value since time is added to the project schedule.

The following illustration shows the difference between lead and lag. Leads and lags must be considered in the project schedule since an abundance of lag time can increase the project duration. An abundance of lead time, however, may increase risks.



Evaluating the Risk Management Plan

We'll discuss risk and risk management completely in Chapter 11. For now, know that risks can alter the project schedule—for better or for worse. This isn't difficult to see. A risk in the project may be identified as delays from the vendor for the equipment needed to complete the project. The response to this risk, should it happen, may be to secure an alternate vendor that charges slightly more for the same equipment but has it in stock. The delay of the equipment with the original vendor may throw the project off schedule, and the additional time to find, purchase, and ship the needed equipment could also add extra time to the project.

Examining the Activity Attributes

The activity attributes can have a direct impact on the project schedule. Some activities are effort driven, which means more effort can reduce the duration. Other activities are of fixed duration—that is, additional effort does nothing to reduce their

expected duration. Activity attributes are the characteristics of the work to be completed, including

- Person(s) responsible for completing each work package
- Where the work will take place (building, city, outdoors)
- Type of activity (electrical, technical, supervised, and so on)
- When the activity must take place (business hours, off-hours, more unusual times)

Creating the Project Schedule

The project manager, the project team, and possibly even the key stakeholders, will examine the inputs previously discussed, and apply the techniques discussed in this section to create a feasible schedule for the project. The point of the project schedule is to complete the project scope in the shortest amount of time possible without incurring exceptional costs, risks, or a loss of quality.

Creating the project schedule is part of the planning process group. It is calendar-based and relies on the project network diagram and the accuracy of time estimates.

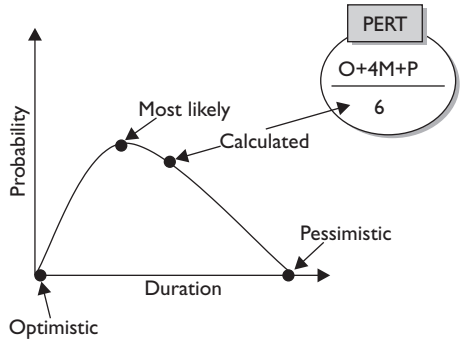
Applying Mathematical Analysis

Mathematical analysis is the process of factoring theoretical early and late start dates and theoretical early and late finish dates for each activity within the PND. The early and late dates are not the expected schedule, but rather a potential schedule based on the project constraints, likelihood of success, and availability of resources, and other constraints. There are three common methods for mathematical analysis:

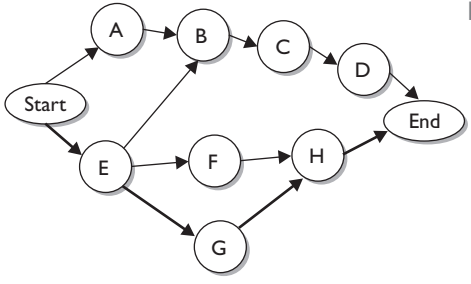
- **Program Evaluation and Review Technique (PERT)** PERT uses a weighted average formula to predict the length of activities and the project. Specifically, PERT uses a "pessimistic," "optimistic," and "most likely" estimate to predict when the project will be completed. Figure 6-6 shows the formula and typical outcome of using PERT. Note that PERT is rarely used in today's project management practices.

FIGURE 6-6

PERT uses a weighted average to predict when the activities will end.



- **Graphical Evaluation and Review Technique (GERT)** GERT uses conditional advancement, branching, and looping of activities and is based on probable estimates. Activities within GERT are dependent on the results of other upstream activities. For example, the results of a work package may determine if additional testing is needed, rework is required, or the project may continue as planned.



- **Critical Path Method (CPM)** This is the most common approach to calculating when a project may finish. It uses a "forward" and "backward" pass to reveal which activities are considered critical. Activities on the critical path may not be delayed; otherwise, the project end date will be delayed. The critical path is the path with the longest duration to completion. Activities not on the critical path have some float (also called slack) that allows some amount of delay without delaying the project end date. The following illustration is an example of the critical path.

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The critical path is used to determine which activities have no float. You can also use the critical path to determine the earliest date for when the project may be completed. There can be more than one critical path in a project. It is possible for the critical path to change.

Calculating Float in a PND

Float, or slack, is the amount of time a delayed task can delay the project's completion. Technically, there are three different types of float:

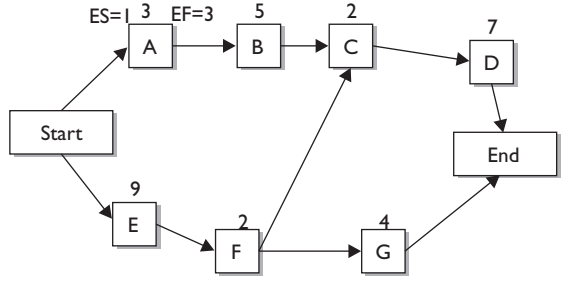
- **Free float** This is the total time a single activity can be delayed without delaying the early start of any successor activities.
- **Total slack** This is the total time an activity can be delayed without delaying project completion.
- **Project slack** This is the total time the project can be delayed without passing the customer-expected completion date.

Most project management software will automatically calculate float, on the PMP exam; however, candidates will be expected to calculate float manually. Don't worry; it's not too tough. Here's the process:

Examine the PND and find the critical path. The critical path is typically the path with the longest duration and will always have zero float. The critical path is technically found once you complete the forward and backward pass. Actually, I would say that you don't know this until you do the forward and backward pass. Start with the forward pass, after the backwards pass you can identify the critical and near critical path, as well as float.

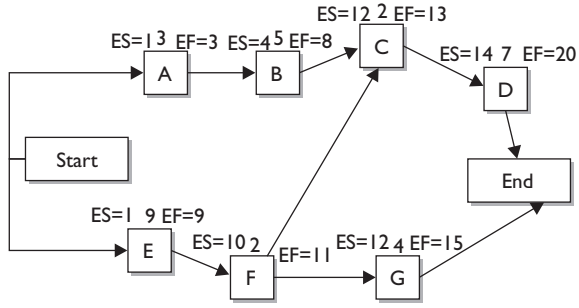
1. The Early Start (ES) and Early Finish (EF) dates are calculated first by completing the "forward pass." The ES of the first task is one. The EF for the first task is its ES, plus the task duration, minus one. Don't let the "minus one value" throw you. If Task A is scheduled to last one day, it would only take one day to complete, right? The ES would be 1, the duration is 1, and the EF would also be one because the activity would finish within one day, not two days. The following illustration shows the start of the forward pass.

III 6-8



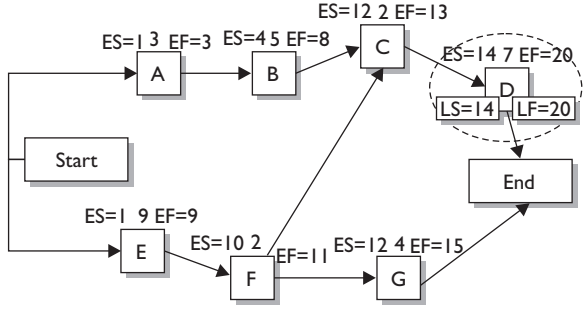
2. The ES of the next task(s) will be the EF for the previous activity, plus one. In other words, if Task A finishes on day eight, Task B will begin on day nine.
3. The EF for the next task(s) equals its ES plus the task duration, minus one. Sound familiar?
4. Now each task moves forward with the forward pass. Use caution when there are predecessor activities; the EF with the largest value is carried forward. The following illustration shows the completed forward pass.

III 6-9



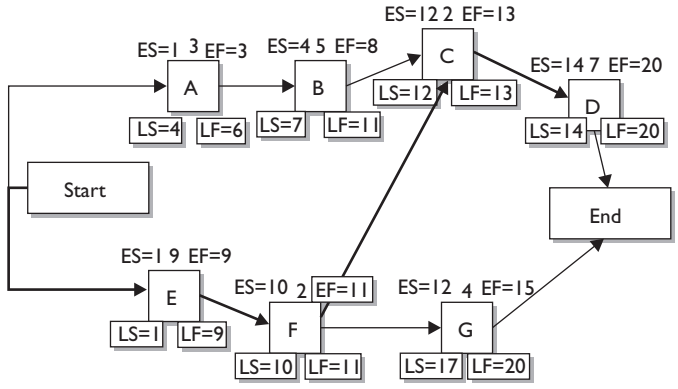
5. After the forward pass is completed, the backward pass starts at the end of the PND. The backward pass is concerned with the Late Finish (LF) and the Late Start (LS) of each activity. The LF for the last activity in the PND equals its EF value. The LS is calculated by subtracting the duration of the activity from its LF, plus one. The one is added to accommodate the full day's work; it's just the opposite of subtracting the one day in the forward pass. Here's a tip: the last activity is on the critical path, so its LS will equal its ES.
6. The next predecessor activity's LF equals the LS of the successor activity minus one. In other words, if Task Z has an LS of 107, Task Y will have an LF of 106. The following illustration shows the process of the backward pass.

III 6-10



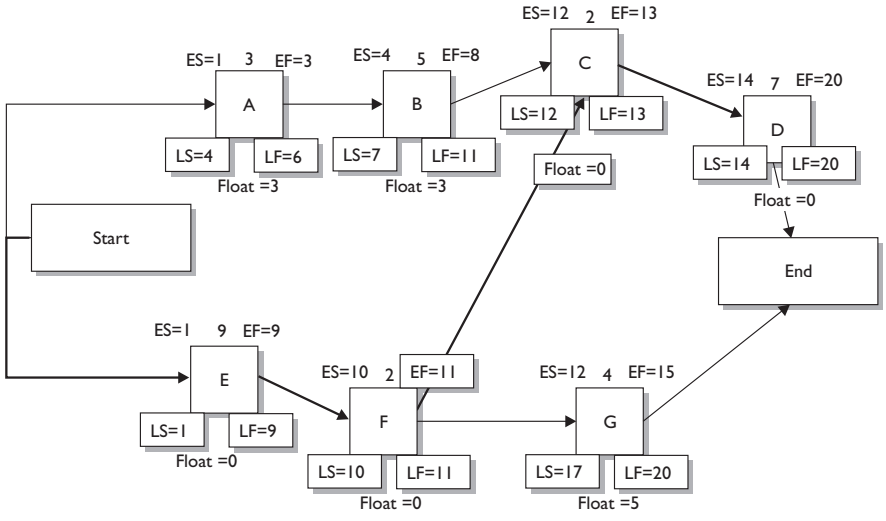
7. The LS is again calculated by subtracting the task's duration from the task's LF, plus one. The following shows the completed backward pass.

Ill 6-11



8. To officially calculate float, the LS is subtracted from the ES and the LF is subtracted from the EF. Recall the total float is the amount of time a task can be delayed without delaying the project completion date. The next illustration shows the completed PND with the float exposed.

Ill 6-12



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You'll have to calculate float on the exam. "Du" means duration when shown in a PND. Always neatly draw the PND on your paper. The same network diagram may be used over and over throughout the exam—this saves time! Finally, find and mark the critical path first on your scratch paper. The question may want to know the float for a task on the critical path, which is zero, of course.

Encountering Scheduling on the PMP Exam

You'll encounter float, scheduling, and critical path activities on the PMP exam. You should count these questions as "gimmies" if you remember a few important rules:

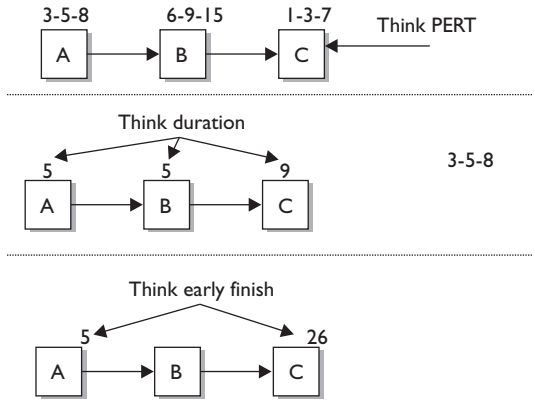
- Always draw out the network diagram presented on your scratch paper; it may be used in several questions.
- Know how to calculate float. (The complete process was shown earlier in the "Calculating Float in a PND" section)
- You may encounter questions that ask on what day of the week a project will end if no weekends or holidays are worked. No problem. Add up the critical path, divide by 5 (Monday through Friday), and then figure out which day of the week the activity will end on.
- You may see something like Figure 6-7 when it comes to scheduling. When three numbers are presented, think PERT; optimistic is the smallest number, pessimistic is the largest, most likely is somewhere between the two. When a number is positioned directly over the tasks, it is the task duration. When a number is positioned to the upper-right of a task, this represents the Early Finish date.

Applying Duration Compression

Duration compression is also a mathematical approach to scheduling. The trick with duration compression, as its name implies, is calculating ways the project can get done sooner than expected. Consider a construction project. The project may be slated to last eight months, but due to the expected cold and nasty weather typical of month seven, the project manager needs to rearrange activities, where possible, to end the project as soon as possible.

FIGURE 6-7

Scheduling follows many rules to arrive at the project destination.



In some instances, the relationship between activities cannot be changed due to hard or soft logic. The relationships must remain as scheduled. Now consider the same construction company that is promised a bonus if they can complete the work by the end of month seven. Now there's incentive to complete the work, but there's also the fixed relationship between activities.

To apply duration compression, the performing organization can rely on two different methods. These methods can be used independently or together and are applied to activities or the entire project based on need, risk, and cost. The methods are

- **Crashing** This approach adds more resources to activities on the critical path to complete the project earlier. When crashing a project, costs are added as the labor expenses increase. Crashing doesn't always work. Consider activities that have fixed duration and won't finish faster with additional resources. The project manager must also consider the cost of the expenses in relation to the gains of completing on time. For example, a construction company may have been promised a bonus to complete the work by a preset date, but the cost incurred to hit the targeted date is more than what the bonus offers.
- **Fast Tracking** This method changes the relationship of activities. With fast tracking, activities that would normally be done in sequence are allowed to be done in parallel or with some overlap. Fast tracking can be accomplished by changing the relation of activities from FS to SS or by adding lead time to downstream activities. For example, a construction company could change the relationship between painting the rooms and installing the carpet by adding lead time to the carpet installation task. Before the change, all of the rooms had to be painted before the carpet installers could begin. With the

added lead time, the carpet can be installed hours after a room is painted. Fast tracking increases risk and may cause rework in the project. Can't you just imagine those workers getting fresh paint on the new carpet?

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It's easy to remember the difference between these two actions. Crashing and cost both begin with C; we're adding resources and too many people will "crash" into each other. Fast tracking is about speeding things up: haste makes waste—risky.

Using a Project Simulation

Project simulations allow a project manager to examine the feasibility of the project schedule under different conditions, variables, and events. For example, the project manager can see what would happen to a project if activities were delayed, vendors missed shipment dates, and external events affected the project.

Simulations are often completed with the Monte Carlo Analysis. The Monte Carlo Analysis, named after the world-famous gambling city, predicts how scenarios may work out given any number of variables. The process doesn't actually churn out a specific answer, but a range of possible answers. When Monte Carlo is applied to a schedule it can examine, for example, the optimistic completion date, the pessimistic completion date, and the most likely completion date for each activity in the project.

As you can imagine in a typical network diagram, there are likely thousands, if not millions, of combinations of tasks that complete early, late, or as expected. Monte Carlo analysis shuffles these combinations, usually through computer software, and offers a range of possible end dates coupled with an expected probability for achieving each end date.

In other words, Monte Carlo Analysis is an odds-maker; the project manager chooses, or is at least influenced, by the end date with the highest odds of completion in ratio to the demands for completion by an expected time. The project manager can then predict with some certainty that the project has an 85 percent chance of completion by a specific date.

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Monte Carlo Analysis can be applied to more than just scheduling. It can be applied to cost, project variables, and most often, risk analysis.

Simulations also provide time to factor in "what-if" questions, worst-case scenarios, and potential disasters. The end result of simulations is to create responses to the feasible situations. Then, should the situations come into play, the project team is ready with a planned response.

Using Resource Leveling Heuristics

First off, a heuristic is a fancy way of saying "rule of thumb." A resource leveling heuristic is a method to flatten the schedule when resources are over-allocated. Resource leveling can be applied using different methods to accomplish different goals. One of the most common methods is to ensure that workers are not overextended on activities. Figure 6-8 is a screenshot from Microsoft Project 2002 where resource leveling has been applied.

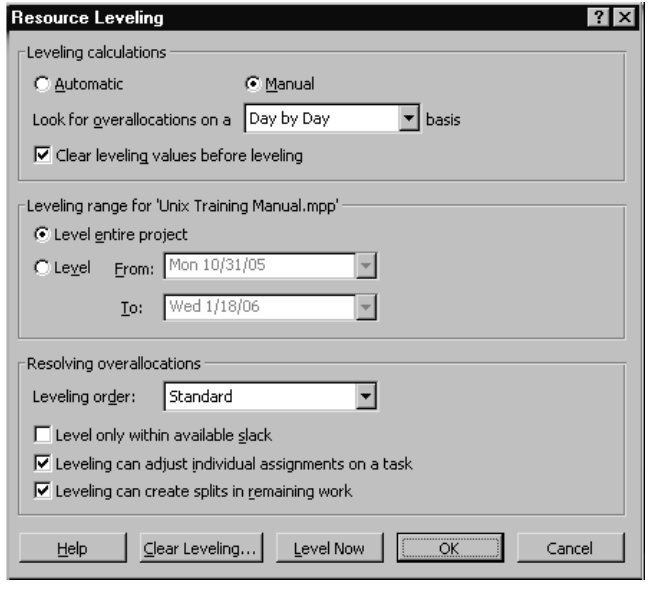
For example, Sarah is assigned to Task C and Task H which both are planned to happen concurrently. Sarah cannot be in two places at once, so resource leveling changes the timing of the activities so Sarah can complete Task C and then move onto Task H. As expected, however, resource leveling often extends the project end date.

Another method for resource leveling is to take resources off of non-critical path activities and apply them to critical-path activities to ensure the project end date is met. This method takes advantage of available slack and balances the expected duration of the non-critical path with the expected duration of the critical path.

Resource leveling also provides for changing the project schedule to allow for long work hours to complete the project work—such as weekends, evenings, or even adding a second or third shift to bring the project back in alignment. Another approach, also part of resource leveling, is to change the resources, tools, or equipment used to

FIGURE 6-8

Resource leveling smoothes the schedule, but may extend the project end date.



complete the project work faster. For example, a project manager could request the printer to use a different, faster printing press to complete the printing activity than what was originally planned for. Of course, these approaches often increase cost.

Finally, some resources may be scarce to the project. Consider a highly skilled technician or consultant that is only available on a particular date to contribute to the project. These resources are scheduled from the project end date, rather than the start date. This is known reverse resource allocation scheduling.

Using a Project Management Software

When it comes to project management software, take your pick: the market is full of them. Project management applications are tools, not replacements, for the project management process. Many of the software titles today automate the processes of scheduling, activity sequencing, work authorization, and other activities. The performing organization must weigh the cost of the PMIS against the benefits the project managers will actually use.

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Don't worry too much about software programs for the exam. Software helps the project manager; it doesn't replace the project manager.

Relying on a Project Coding Structure

The coding structure identifies the work packages within the WBS and is then applied to the PND. This allows the project manager, the project team, experts, and even key stakeholders, to extract areas of the project to examine, evaluate, and inspect. For example, a project to create a catalog for a parts distributor may follow multiple paths to completion. Each path to completion has its own "family" of numbers that relate to each activity on the path. Consider Table 6-2:

TABLE 6-2 Possible Paths in Creating a Catalog

Path	Coding for Path	Typical Activities
Artwork	4.2	Concept (4.2.1) Logos (4.2.2) Font design (4.2.3)
Photography	4.3	Product models (4.3.1) Airbrushing (4.3.2) Selection (4.3.3)

TABLE 6-2

Possible Paths in Creating a Catalog *(continued)*

Path	Coding for Path	Typical Activities
Content	4.4	Message (4.4.1) Copywriting (4.4.2) Editing (4.4.3) Rewrites (4.4.4)
Print	4.5	Signatures (4.5.1) Plates (4.5.2) Four-color printing (4.5.3)
Bind	4.6	Assembly (4.6.1) Bindery (4.6.2) Trimming (4.6.3) Shrink-wrap (4.6.4)
Distribution	4.7	Packaging (4.7.1) Labeling (4.7.2) Shipping (4.7.3)

Considering the Outputs of Schedule Development

After all the challenges of examining, sequencing, and calculating the project activities, a working schedule is created. Schedule development, like most of project management's planning processes, moves through progressive elaboration. As the project moves forward, discoveries, risk events, or other conditions may require the project schedule to be adjusted. In this section, we'll discuss the project schedule and how it is managed.

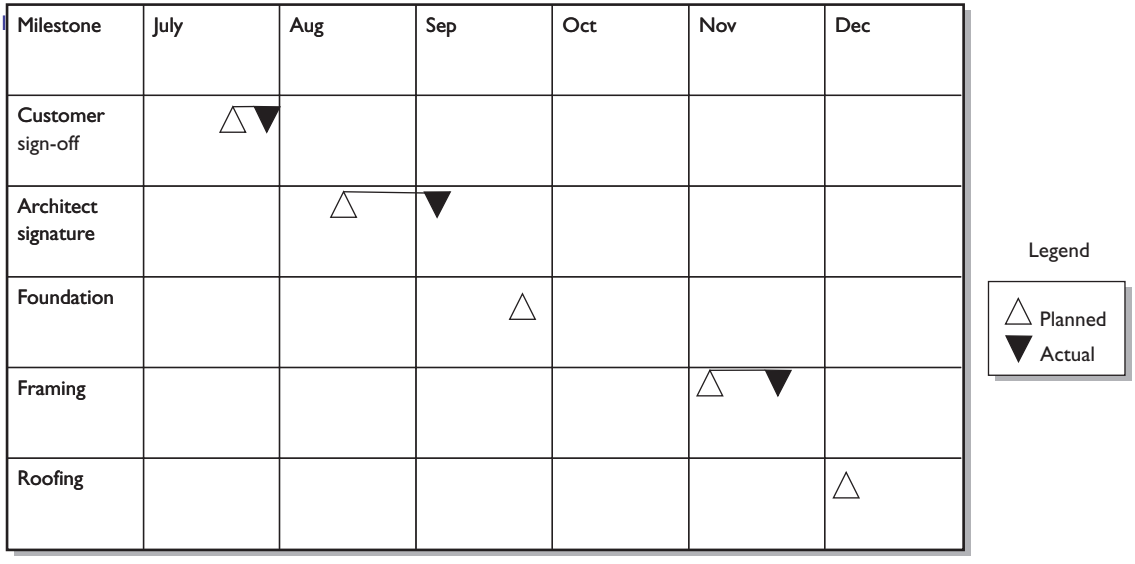
Examining the Project Schedule

The project schedule includes, at a minimum, a date for when the project begins and a date when the project is expected to end. The project schedule is considered proposed until the resources needed to complete the project work are ascertained. In addition to the schedule, the project manager should include all of the supporting details. Project schedules can be presented in many different formats, such as:

- **Project Network Diagram** Illustrates the flow of work, the relationship between activities, the critical path, and the expected project end date. PNDs when used as the project schedule should have dates associated with each project activity to show when the activity is expected to start and end.

- **Bar charts** These show the start and end dates for the project, and the activity duration against a calendar. They are easy to read. Scheduling bar charts are also called Gantt charts.
- **Milestone charts** Plot out the high-level deliverables and external interfaces, such as a customer walk-through, against a calendar. Milestone charts are similar to a Gantt chart, but with less detail regarding individual activities. The following is an example of a milestone chart.

III 6-1



Utilizing the Schedule Management Plan

The schedule management plan is a subsidiary plan of the overall project plan. It used to control changes to the schedule. A formal schedule management plan has procedures that control how changes to the project plan can be proposed, accounted for, and then implemented. An informal schedule management plan may consider changes on an instance-by-instance basis.

Updating the Resource Requirements

Due to resource leveling, additional resources may need to be added to the project. For example, a proposed leveling may extend the project beyond an acceptable completion date. To reach the project end date the project manager elects to add additional

resources to the critical path activities. The resources the project manager adds should be documented, the associated costs accounted for, and approved.

Controlling the Project Schedule

Schedule control is part of Integrated Change Management, as discussed in Chapter 4. Throughout a typical project, events will happen that may require updates to the project schedule. Schedule control is concerned with three processes:

- The project manager works with the factors that can cause schedule change in an effort to confirm that the changes are agreed upon. Factors can include project team members, stakeholders, management, customers, and project conditions.
- The project manager examines the work results, conditions, and demands to know the schedule has changed.
- The project manager manages the actual change in the schedule.

Managing the Inputs to Schedule Control

Schedule control, the process of managing changes to the project schedule, is based on several inputs:

- Project schedule
- Performance reports
- Change requests
- The schedule management plan

Applying a Schedule Control System

A Schedule Control System is a formal approach to managing changes to the project schedule. It considers the conditions, reasons, requests, costs, and risks or making changes. It includes methods of tracking changes, approval levels based on thresholds, and documentation of approved or declined changes. The Schedule Control System process is part of integrated change management.

Measuring Project Performance

Poor performance may result in schedule changes. Consider a project team that is completing a work on time, but all of the work results are unacceptable. The project team may be rushing through their assignments to meet their deadline. To compensate for this, the project may be changed to allow for additional quality inspections, and more time for activity completion. Project performance is often based on earned value management, which we'll discuss in Chapter 10.

Returning to Planning

Planning is an iterative process. If the schedule, work results, or performance is unacceptable, the project manager should revisit the planning processes to determine the root cause. Additional planning is also needed when the scope may be changed, risks are discovered, and when other project events happen. Additional planning is expected throughout most projects.

Relying on *Project Management Software*

Most project management software can simulate the result of changes to a project schedule. Project management software can predict what may happen when a task is delayed, additional tasks are added, or the relationship between activities is edited. Project management can streamline schedule control.

Examining the Schedule Variance

The project manager must actively monitor the variances between when activities are scheduled to end and when they actually end. An accumulation of differences between scheduled and actual dates may result in a schedule variance.

The project manager must also pay attention to the completion of activities on paths with float, not just the critical path. Consider a project that has eight different paths to completion. The project manager should first identify the critical path, but should also identify the float on each path. The paths should be arranged and monitored in a hierarchy of the path with smallest float to the path with the largest float. As activities are completed, the float of each path should be monitored to identify any paths that may be slipping from the scheduled end dates.

Updating the Project Schedule

So what happens when a schedule change occurs? The project manager must ensure that the project schedule is updated to reflect the change, document the change, and follow the guidelines within the schedule management plan. Any formal processes, such as notifying stakeholders or management, should be followed.

Revisions are a special type of project schedule change, which cause the project start date, and more likely, the project end date to be changed. They typically stem from project scope changes. Because of the additional work the new scope requires, additional time is needed to complete the project.

Schedule delays, for whatever reason, may be so drastic that the entire project has to be rebaselined. Rebaselining is a worst-case scenario and should only used be when adjusting for drastic, long delays. When rebaselining happens, all of the historical information up to the point of the rebaseline is eliminated. Schedule revision is the preferred, and most common, approach to changing the project end date.

Applying Corrective Action

Corrective action is any method applied to bring the project schedule back into alignment with the original dates and goals for the project end date. Corrective actions are efforts to ensure future performance meets the expected performance levels. It includes

- Extraordinary measures to ensure work packages complete as scheduled
- Extraordinary measures to ensure work packages complete with as little delay as possible
- Root-cause analysis of schedule variances
- Implementing measures to recover from schedule delays

Writing the Lessons Learned

Lessons learned on creating the schedule, changes to the project schedule, and response to variances are needed as part of the project's historical information. Recall that lessons learned documentation happens throughout the project plan, not just at the conclusion of the project.

CERTIFICATION SUMMARY

Projects cannot last forever—thankfully. To effectively finish and manage a project, a project manager must be able to effectively manage time. Within a project there can be many factors that affect the project length: activity duration, project calendars, resource calendars, vendors, activity sequencing, and more. Time management begins with the constraints of the product schedule, the project calendar, the resource calendars, as well as the activities and their expected duration.

Many projects can rely on project templates that have worked before. Other projects, new and never-attempted technology, require that a project schedule be created from scratch. The WBS contributes to the activity list, which in turn, allows the project manager and the project team to begin activity sequencing.

Activities to be sequences must be estimated. The project manager and the project team must evaluate the required time to complete the work packages. The project manager can rely on a number of estimating methods to come to a predicted duration for activities. For example, a project manager may use analogous estimation of historical data to provide the needed estimate. Or, the project manager may use a parametric model to predict the amount of time for the activities. The importance of estimating is that each work package is considered and its duration calculated.

Within the process of activity sequencing there will be hard logic and soft logic. Hard logic is the mandatory relationships between activities: the foundation must be in place before the house framing can begin. Soft logic allows the relationship and order of activities to be determined based on conditions, preferences, or other factors. For example, the landscaping will happen before the house is painted so that dirt and dust won't get onto the fresh paint.

The relationships of activities are illustrated within a network diagram. Network diagrams show the path from start to completion and identify which activities are on the critical path. Of course, the critical path is the path with the longest duration and typically has zero slack or float. Activities on the noncritical paths may be delayed to the extent that they do not delay activities on the critical path.

Finally, project team members may have a tendency to bloat their duration estimates. Bloating the work to allow for "wiggle room" on assignments can cause durations to swell way beyond the practical completion of the project. In lieu of bloated estimates, project team members and the project manager should use a percentage of the project time as management reserve. When activities are late, the tardiness of the work is borrowed from management reserve rather than tacked onto the conclusion of the project.

Key Terms

To pass the PMP exams, you will need to memorize these terms and their definitions. For maximum value, create your own flashcards based on these definitions and review them daily. The definitions can be found within this chapter and in the glossary.

activity list	FNET	quantitative estimating
activity on arrow	fragnets	resource calendar
activity on node	GERT	resource leveling heuristics
activity sequencing	hard logic	schedule control
analogous estimating	lag	schedule management plan
CPM	lead	schedule variance
crashing	mandatory dependencies	SNET
discretionary dependencies	Monte Carlo Analysis	soft logic
fast tracking	network templates	start-to-finish
finish-to-finish	PERT	start-to-start
finish-to-start	Precedence Diagramming Method	subnets
float	project calendar	

TWO-MINUTE DRILL

Sequencing Activities

- ❑ Projects are made up of sequential activities to create a product. The WBS and the activity list serve as key input to the sequencing of project activities. The science of arranging, calculating, and predicting how long the activities will take to complete allows the project manager to create a schedule and then predict when the project will end.
- ❑ Hard logic is the approach that requires activities to happen in a specific order due to the nature of the work. For example, configure a computer workstation's operating systems before adding the software.
- ❑ Soft logic is a "preferred" method of arranging activities based on conditions, guidelines, or best practices. For example, the project manager prefers all of the photocopying of a user manual to be complete before any bindery work on the manual begins.
- ❑ The sequence of activities is displayed in a network diagram. The network diagram illustrates the flow of activities and the relationship between activities. The Precedent Diagramming Method is the most common approach to arranging activities visually.

Estimating Activity Durations

- ❑ Activity duration estimates are needed to calculate how long the project will take to complete. Estimates can come from project team members, commercial databases, expert judgment, and historical information.
- ❑ Analogous estimating relies on historical information to predict how long current project activities should last.
- ❑ Quantitative estimates use a mathematical model to calculate how long activities should take based on units, duration, and effort.

Evaluating Time and Duration

- ❑ The resources to complete the project activities must be considered. The project manager must evaluate the skill set, the experience, and ability to get the work done.

- ❑ The project manager must evaluate applying additional resources to effort-driven activities to reduce their duration. Adding resources does not reduce fixed-duration activities' durations.
- ❑ The calendar of the project is the time when the project work may take place. The project manager must consider access to the workplace, project schedule, organization holidays, and events that affect the project calendar.
- ❑ The resource calendar reflects when the project resources (project team members, consultants, and so on) are available to complete the project work.

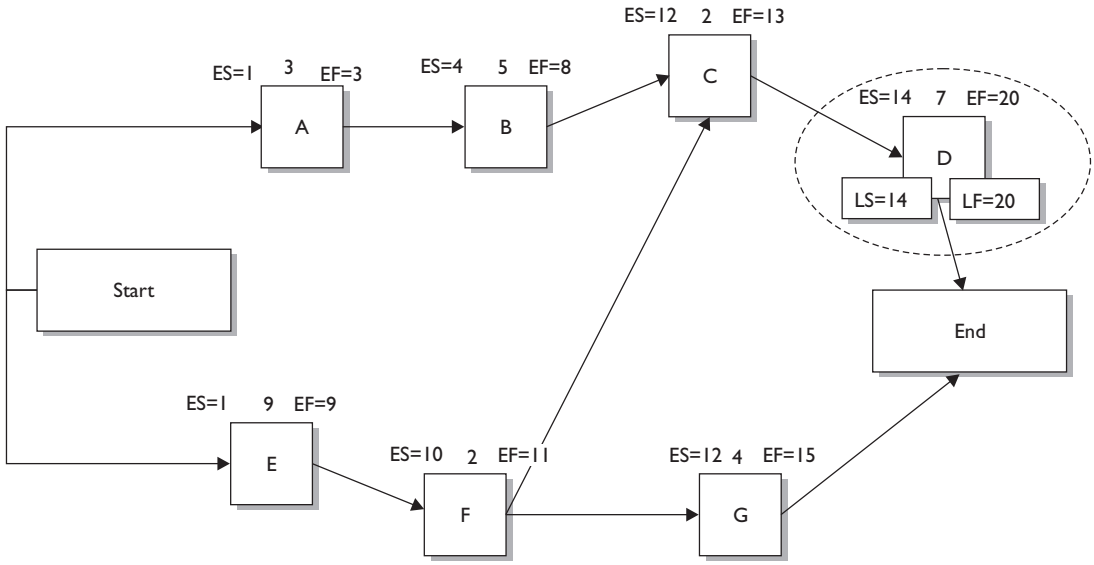
Determining the Project Duration

- ❑ The critical path is the longest path to completion in the network diagram. Activities on the critical path have no float or slack. Free float is the amount of time an activity can be delayed without affecting the next activity's scheduled start date. Total float is the amount of time an activity can be delayed without affecting the project end date.
- ❑ Duration compression is applied to reduce the length of the project or to account for project delays. Crashing adds resources to project activities and usually increases cost. Fast tracking allows activities to happen in tandem and usually increases risk.
- ❑ The schedule management plan must be consulted when project schedule changes occur, are proposed, or are needed. The Schedule Control System implements the schedule management plan and is part of integration change management.

SELF TEST

1. You are the project manager of the JHG Project. This project has 32 stakeholders and will require implementation activities in North and South America. You have been requested to provide a duration estimate for the project. Of the following, which will offer the best level of detail in your estimate?
   A. WBS
   B. Order of magnitude
   C. Requirements document
   D. Stakeholder analysis
2. Michael is the project manager of the 78GH Project. This project requires several members of the project team to complete a certification class for another project the week of November 2. This class causes some of the project activities on Michael's activities to be delayed from his target schedule. This is an example of which of the following?
   A. Hard logic
   B. External dependencies
   C. Soft logic
   D. Conflict of interest
3. Which of the following best describes GERT?
   A. PDM
   B. Network template
   C. Conditional diagramming methods
   D. ADM
4. As the project manager for the DFK Project, you are reviewing your project's network diagram (as shown in the following illustration):

III 6-14



Given the diagram, what is the relationship between tasks F and G?

A. FS
B. SS
C. FF
D. SF

5. You are the project manager for the LLL Project. Steven, a project team member, is confused about network diagrams. Specifically, he wants to know what the critical path is in a network diagram. Your answer is which one of the following?

A. The critical path is the network that hosts the activities most critical to the project success.
B. The critical path is the path with the longest duration.
C. The critical path is always one path that cannot be delayed or the entire project will be delayed.
D. The critical path is the path from start to completion with no deviation from the project plan.

6. What is the difference between PDM and ADM?

A. ADM places activities on arrows; PDM places activities on nodes.
B. ADM is also known as AOA, while PDM is also known as GERT.
C. ADM hosts activities on nodes, while PDM hosts activities on arrows.
D. PDM can have two types of relationships between tasks, while ADM can have only type of relationship between tasks.

7. The purpose of using GERT is which of the following?
   A. Allows for float to be distributed across all paths to completion
   B. Allows for loops and conditional branches
   C. Requires all paths to completion to intersect at quality audits
   D. Requires all paths to completion to intersect at scope verification checkpoints
8. Where is a project manager most likely to experience a subnet?
   A. WBS
   B. Kill points
   C. GERT charts
   D. Network template
9. You are the project manager for the POL Project. This project will use PERT to calculate the estimates for activity duration. For activity D, you have the following information: P=9, O=4, M=5. What is the result of PERT?
   A. 18 weeks
   B. 5.5 weeks
   C. 33.33 days
   D. 3 weeks
10. You are the project manager for the YKL Project. This project will impact several lines of business at completion. Each milestone in the project is scheduled to end so the work does not impact current business cycles. This is an example of which one of the following?
   A. Constraint
   B. Expert judgment
   C. WBS scheduling
   D. Soft logic
11. You are the project manager for the MNB Project. You and your project team are about to enter into the activity duration estimating process. Which of the following will not be helpful in your meeting?
   A. Constraints
   B. Assumptions
   C. The project charter
   D. Identified risks

12. You are the project manager for a new training program at your customer's site. This program will require each of the customer's employees to attend the half-day class and complete an assessment exam. You will be completing the training at the customer's facility, and will need a trainer for the duration of the training, which is six months. This is an example of which of the following?

A. Resource requirements
B. Assumption
C. Cost constraint
D. A human resource issue

13. You are the project manager for a construction company. Your firm has been contracted to complete the drilling of a well for a new cabin in Arkansas. The specification of the well is documented, but your company has little experience in well drilling in Arkansas. The stakeholder is concerned your time estimates are not accurate as the soil and rock in Arkansas are much different than the soil in your home state. Which one of the following can you use to ensure your project estimates are accurate?

A. Order of magnitude
B. Commercial duration estimating databases
C. Local contractors
D. Soil samplings from the Arkansas government

14. You are the project manager for your organization. You and your project team are in conflict on the amount of time allotted to complete certain activities. Several of the team members are wanting to bloat the time associated with activities to ensure they will have enough time to complete their tasks should something go awry. The law of economics that these tasks may suffer from is which one of the following?

A. Parkinson's Law
B. The law of diminishing returns
C. Hertzberg's theory of motivation
D. Oligopoly

15. You are the project manager for your organization. You and your project team are in conflict on the amount time allotted to complete certain activities. Several of the team members are wanting to bloat the time associated with activities to ensure they will have enough time to complete their tasks should something go awry. Instead of overestimating their project activities, the project team should use which of the following?

A. Capitol reserve

B. Contingency plans
C. Contingency reserve
D. Assumptions of plus or minus a percentage

16. Which of the following is not an output from the activity duration estimating process?

A. WBS
B. Activity list updates
C. Basis of estimates
D. Duration estimates

17. You are the project manager for the 987 Project. Should this project run over schedule, it will cost your organization $35,000 per day in lost sales. With four months to completion, you realize the project is running late. You decide, with management's approval, to add more project team members to the project plan to complete the work on time. This is an example of which of the following?

A. Crashing
B. Fast tracking
C. Expert judgment
D. Cost benefit analysis

18. You are the project manager for the 987 Project. Should this project run over schedule, it will cost your organization $35,000 per day in lost sales. With four months to completion, you realize the project is running late. You decide, with management's approval, to change the relationship between several of the work packages so they begin in tandem rather than sequentially. This is an example of which one of the following?

A. Crashing
B. Fast tracking
C. Expert judgment
D. Cost benefit analysis

19. Chris, a project manager for his company, is explaining the difference between a Gantt chart and a milestone chart. Which of the following best describes a Gantt chart?

A. A Gantt chart depicts what was planned against what actually occurred.
B. A Gantt chart depicts the work in the project against the work that has been completed.
C. A Gantt chart depicts the work in the project against a calendar.
D. A Gantt chart depicts the work in the project against each resource's calendar.

20. Which of the following is a correct attribute of the critical path?

A. It determines the earliest completion date
B. It has the smallest amount of float
C. It has the most activities in the PND
D. It is the path with the most expensive project activities

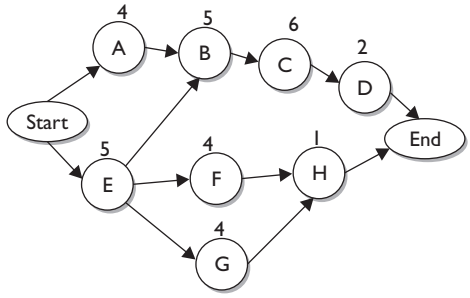
21. You are the project manager for a construction project. Your foreman informs you that, due to the humidity, the concrete will need to cure for an additional 24 hours before the framing can begin. To accommodate the requirement, you add _____ time to the framing activity.

A. Lead
B. Lag
C. Delay
D. Slack

22. A heuristic is a _____?

A. Rule of thumb
B. Regulation
C. A regulation internal to an organization
D. A best method of implementing an activity

23. You are the project manager for a project with the following network diagram.



Studying the diagram, which path is the critical path?

A. ABCD
B. EBCD
C. EFH
D. EGH

24. Bertha is the project manager for the HAR Project. The project is behind schedule and Bertha has elected, with management's approval, to crash the critical path. This process adds more what? (Choose the best answer.)

A. Cost
B. Time
C. Risk
D. Documentation

25. Bertha is the project manager for the HAR Project. The project is behind schedule and Bertha has elected, with management's approval, to fast track the critical path. This process adds more what? (Choose the best answer.)

A. Cost
B. Time
C. Risk
D. Documentation

SELF TEST ANSWERS

1. ☑ **A.** The WBS is the best choice for this scenario.
   ☒ **B** is incorrect because the order of magnitude provides little information for accurate estimating. **C,** while tempting, is incorrect because the requirements document lists the high-level deliverable, while the WBS provides more detail. **D** is incorrect because stakeholder analysis does not provide enough information to accurately predict when the project will end.

2. ☑ **B.** Before the work can begin, the certification class must be completed.
   ☒**A** is incorrect; hard logic is the mandatory sequencing of particular events. **C** is incorrect because there is no preferential logic. **D** is incorrect because it does not apply to this scenario.

3. ☑ **C.** GERT, Graphical Evaluation and Review Technique, allows for conditional advancement.
   ☒ **A, B,** and **C** are all incorrect because these describe other network diagrams.

4. ☑ **A.** G is slated to start immediately after F, so this is a finish-to-start relationship. In other words, F must finish so G may start.
   ☒ **B, C,** and **D** are all incorrect relationships.

5. ☑ **B.** The critical path is always the path with the longest duration.
   ☒ **A** is incorrect because the critical path hosts the activities, not a network. **C** is a distracter and is incorrect because there can be more than one critical path in a network diagram. **D** is incorrect because it does not adequately describe the critical path.

6. ☑ **A.** ADM, the Arrow Diagramming Method, is also known as "Activity-on-Arrow," while PDM, the Precedence Diagramming Method, places activities on nodes. PDM is also known as "Activity-on-Nodes."
   ☒ **B** and **C** are incorrect because they do not accurately describe ADM and PDM. **D** is incorrect because PDM is allowed four different relationship types: FS, SF, FF, and SF.

7. ☑ **B.** GERT allows for branching and loopbacks.
   ☒ **A, C,** and **D** are all incorrect because they do not accurately describe GERT.

8. ☑ **D.** Subnets are often included in network templates to summarize common activities in a project.
   ☒ **A, B,** and **C** do not use subnets.

9. ☑ **B.** The formula for pert is (P+4M+O)/6. In this instance, the outcome is 5.5 weeks.
   ☒ **A, C,** and **D** are incorrect calculations, so they are incorrect.

10. ☑ **D.** Soft logic allows the project manager to make decisions based on conditions outside of the project, best practices, or guidelines.
    ☒ **A** is incorrect because this is not an example of constraints since the project manager is not required to use soft logic. **B** and **C** are incorrect; they do not describe the scenario fully.

11. ☑ **C.** The project charter is not an input to the activity duration estimating process.
☒ Choices **A, B,** and **D** are all correct choices because they are inputs to activity duration estimating.

12. ☑ **A.** The trainer is required for the project for six months.
☒ **B, C,** and **D** are incorrect because they do not describe the resource requirement of the trainer on the project.

13. ☑ **B.** Commercial duration estimating databases are valid resources to confirm or base time estimates upon.
☒ **A** is incorrect because order of magnitude offers very little detail on time estimates. **C** is incorrect because local contractors are not the best source for confirming time estimates; the question does not define if the contractors are local to Arkansas or to your home state. **D** is incorrect because commercial duration estimating databases are much more reliable in this scenario.

14. ☑ **A.** Parkinson's Law states that work will expand to fulfill the time allotted to it.
☒ Bloated tasks will take all of the time allotted. Management reserve should be used instead. **B** is incorrect because this describes the relationship between effort, duration, and the maximum yield. **C** is incorrect because it describes personalities and worker motivation. **D** is incorrect because an oligopoly is a procurement issue where there are few vendors available to choose from; the vendors may seemingly have checks and balances with each other.

15. ☑ **C.** Rather than bloat activities, projects should use contingency reserve. Contingency reserve is a portion of the project schedule allotted for time overruns on activities.
☒ **A** is incorrect because it does not describe the scenario. **B** is incorrect because contingency plans are a response to risk situations. **D** is incorrect because it describes a range of variance.

16. ☑ **A.** The WBS is not an output of activity duration estimating.
☒ Choices **B, C,** and **D** are incorrect because they are outputs of activity duration estimating.

17. ☑ **A.** When more resources are added to a project to complete the work on time, this is called crashing.
☒ **B** is incorrect; fast tracking is the process of changing the relationship between activities to allow tasks to overlap. **C** is incorrect because expert judgment is not used in this scenario. **D** is incorrect; cost benefit analysis may be part of the process to decide the value of adding more workers to the schedule, but it is not the process described.

18. ☑ **B.** Fast tracking allows activities to operate in tandem with each other rather than sequentially.
☒ **A** is incorrect; when more resources are added to a project to complete the work on time, this is called crashing. **C** is incorrect, because expert judgment is not used in this scenario. **D** is

incorrect; cost benefit analysis may be part of the process to decide the value of fast tracking the schedule, but it is not the process described.

19. ☑ **C.** A Gantt chart is a bar chart that represents the duration of activities against a calendar. The length of the bars represent the length of activities while the order of the bars represent the order of activities in the project.
☒ **A** and **B** are incorrect because this describes a tracking Gantt. D is incorrect because this does not describe a Gantt chart.

20. ☑ **A.** Of all the choices presented, A is the best description of the critical path. The critical path is the path with the longest duration. There can be instances, however, when the project's expected end date is well beyond the duration of the scheduled work. In such cases, the critical path is considered the path with the least amount of float.
☒ Choices **B, C,** and **D** are incorrect because they are false descriptions of the critical path. The critical path has no float, has the longest duration, and does not necessarily have the most expensive activities.

21. ☑ **B.** You will add lag time to the framing activity. Lag is waiting time.
☒ **A** is incorrect; lead time allows activities to overlap. **C** is not the correct choice. **D** is also incorrect because slack is the amount of time a task can be delayed without delaying the scheduled start date of dependent activities.

22. ☑ **A.** Heuristic is simply a rule of thumb.
☒ **B, C,** and **D** are all incorrect; these choices do not describe heuristics.

23. ☑ **B** is the critical path because EBCD is the longest path to completion at 18 days.
☒ **A, C,** and **D** are incorrect because these paths have float.

24. ☑ **A.** Crashing involves adding resources, which typically increases cost.
☒ **B** is incorrect because crashing is an effort to reduce time, not add it. **C** may be correct, but it is not the best answer. **D** is incorrect.

25. ☑ **C.** Fast tracking adds risk as tasks are allowed to overlap.
☒ **A** may be correct in some instances, but it is not the best choice here. **B** is incorrect because Bertha wants to remove time, not add it. **D** is also incorrect.